28840/WO/1

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 December 2000 (14.12.2000)

PCT

(10) International Publication Number
WO 00/75687 A1

(51) International Patent Classification[7]: G01S 7/40, 13/93

(21) International Application Number: PCT/SE00/01191

(22) International Filing Date: 8 June 2000 (08.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9902140-4 8 June 1999 (08.06.1999) SE

(71) Applicant *(for all designated States except US)*: CELSIUSTECH ELECTRONICS AB [SE/SE]; S-175 88 Järfälla (SE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: KAMEL, Magnus [SE/SE]; Körsbärsvägen 9, S-114 23 Stockholm (SE).

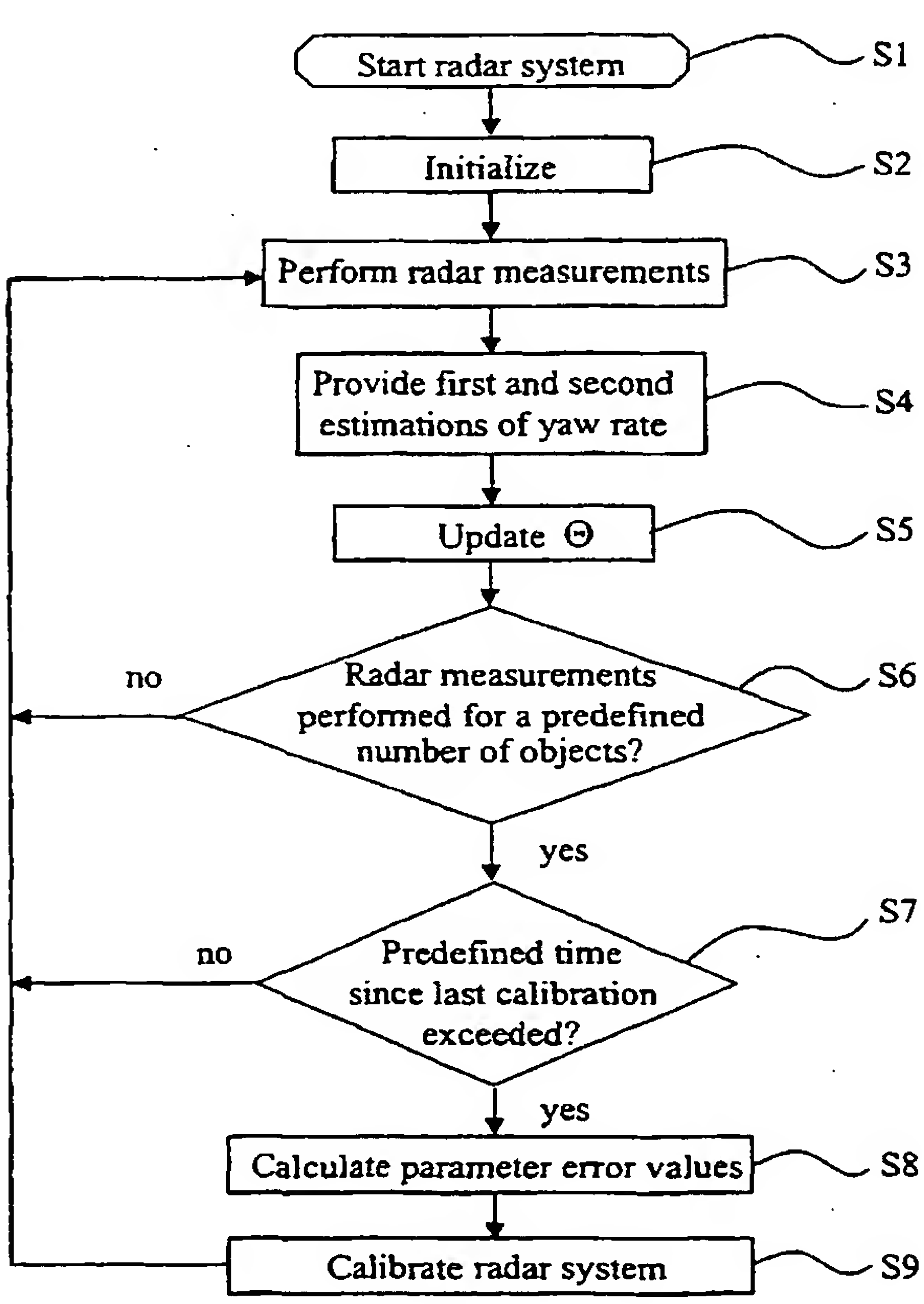
(74) Agent: AWAPATENT AB; P.O. Box 45086, S-104 30 Stockholm (SE).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KR (utility model), KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,

[Continued on next page]

(54) Title: METHOD FOR PERFORMING RADAR MEASUREMENTS AND USE OF THE METHOD FOR CALIBRATING THE RADAR SYSTEM



(57) Abstract: The present invention relates to a method for performing radar measurements with a vehicle mounted radar system. The results of first and second measurements related to a position of an object are compared. The measurements are associated with assumed parameter errors which are derived during the comparison and which are taken into consideration during future radar measurements. Thus, the radar system is calibrated while performing normal radar measurements.

WO 00/75687 A1

IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD FOR PERFORMING RADAR MEASUREMENTS AND USE OF THE METHOD FOR CALIBRATING THE RADAR SYSTEM

Technical field of the invention

The present invention relates to a method for performing radar measurements with a vehicle mounted radar system. The invention also relates to the use of such a method in a vehicle mounted radar system.

Technical background

Radar systems mounted on vehicles such as cars, buses, lorries and the like are currently being developed. The purpose of such systems are to provide functions assisting the driver of the vehicle with features such as cruise control, collision warning and collision avoidance, the functions being based on the detection of vehicles, stationary objects, and other objects in front of the vehicle.

Before such a radar system can be used, the system has to be mounted on the vehicle and be subject to some kind of calibration procedure, either at the vehicle factory or at a service station. The requirements on a precise mounting and/or a calibration of the radar system are very high in order to ensure a correct operation of the system. Moreover, it will probably be required to perform re-calibrations of the system at regular intervals at an appropriate service station or the like.

In prior art, calibration, or adjustment, of a radar sensor in a radar system mounted on a vehicle, such as a car, is often performed in a similar way to headlamp adjustment. The radar sensor assembly has the same design as a headlamp assembly and is equipped with alignment screws. With a radar reflector positioned in front of the car, adjustments are performed in the car factory or in a service station using the alignment screws. Such calibrations, and re-calibrations, needed in order to

obtain, and maintain, an operation which is as correct as possible, are time consuming and costly for the owner of the vehicle.

The published European patent application EP 0 899 581 discloses a system for automatically measuring and compensating for any angle of misalignment of a forward-looking radar sensor of a vehicle. A trajectory line of a target is estimated and the angle of misalignment is estimated from the angle between the trajectory line and the path of travel of the radar host vehicle.

The published patent US 6 670 963 discloses a radar apparatus which calculates a correction value for an error between the beam emission axis and a forward running path of the radar host vehicle.

Summary of the invention

An object with the present invention is to provide an improved method for performing radar measurements with a vehicle mounted radar system that eliminates the need for calibrating the radar system at a vehicle manufacturer or at a vehicle service station.

According to the present invention, this objects is achieved by a method and use of a method having the features as defined in the appended claims.

According to a first aspect of the present invention, there is provided a method for performing radar measurements with a vehicle mounted radar system, including the steps of:

assuming that said radar system is associated with parameter errors, which errors include a presumed offset of a horizontal yaw rate sensor measurement and a presumed erroneous alignment of a radar antenna;

transmitting a radar microwave signal;

performing first and second measurements related to a position of a stationary object;

comparing the results from the first and the second measurements, while assigning that at least either of

these measurements is dependent upon the assumed parameter errors;

deriving a new presumed yaw rate offset and a new presumed erroneous antenna alignment based on a result of said comparing step; and

performing radar measurements under the assumption of the new derived parameter errors.

According to a second aspect, the invention provides use of a method in a vehicle mounted radar system for electrically calibrating the radar system when performing radar measurements with the radar system.

In the present invention, the radar system includes a radar sensor for transmitting and receiving radar beams, and processing means, such as a Signal Processing Unit, for processing measurement data derived from received radar signal reflections. For the purpose of course prediction, the radar system further includes a yaw rate sensor which provides information on the present curvature of the vehicle's directional movement.

One advantage is that no precise calibrations of the radar system has to be performed at a factory, service station, or the like, after the radar system has been mounted on the vehicle, but such calibrations are performed automatically during normal operational radar measurements.

Another advantage with the method of the invention is that calibration of the radar system is performed both with respect to the alignment of the radar sensor antenna and with respect to the offset of the yaw rate sensor measurements, thereby improving the overall performance and the accuracy of the radar system.

With the radar system, at least two different measurements related to a position of a stationary object are performed. It is assumed that the antenna alignment and the yaw rate sensor effects these measurements due to an erroneous alignment and an offset of the measured yaw rate value, respectively. By comparing the different

measurements related to a position of an object, assigned parameter errors of the kind mentioned are derived and taken into consideration during future radar measurements.

It should be noted that the result of the measurements relating to a position of an object can define any parameter which is possible to measure directly or to calculate from the measurements, as long as at least one of the measurements can be derived from a combination of radar measurement data and assumed parameter errors of the kind mentioned above. Examples of parameters that are based on measurement results are the horizontal yaw rate of the vehicle hosting the radar system and the angle in the horizontal plane to the stationary object with respect to the directional axis of the radar system antenna.

The comparison can be performed in a numerous ways. According to one embodiment, the comparison includes minimising a mean square error between the results of the first and the second measurements relating to the position of the object. According to another embodiment, the comparison is performed as an iterative process, each iteration comparing the result of one of the first measurements with the result of one of the second measurements.

The method of the invention is performed with respect to one or more stationary objects, wherein each stationary object gives rise to one or more results of first measurements and one or more results of second measurements. When basing the calibration on several results of measurements of a stationary object, the system performs a number of consecutive radar measurements on the object while simultaneously tracking the object.

Preferably, the provision of measurement results based on normal operational radar measurements and the following calibration of the radar system, is a radar

system process that is performed continuously by the radar system when the system is in use on a moving vehicle. Thus, the invention provides a method which repeatedly controls the calibration of the radar system while performing normal operational radar measurements.

With these regular calibrations, or re-calibrations, of the radar system, the information which is based on the radar measurement data, and provided to a user of the radar system, will always be reliable and up to date.

In order to achieve as reliable calibrations as possible, it is preferred to calibrate the radar system after having performed radar measurements with respect to a certain number of stationary objects, for example a couple of hundred objects. It is also preferred to calibrate the radar system at regular time intervals.

According to the invention, the radar system is adapted to be mounted on a land based vehicle, such as a car, bus or lorry.

The radar sensor included by the radar system is preferably an FMCW-radar sensor (Frequency Modulated Continuous Wave).

Hence, the present invention provides a method which makes calibration and subsequent re-calibrations of the vehicle mounted radar system redundant, i.e. there is no need for any initial calibration or subsequent regular service of the radar system at a service station or the like. The antenna of the radar sensor will automatically be aligned with the directional axis of the vehicle, i.e. with the optimal direction of the antenna. This will clearly lower the cost for maintenance of the radar system. Furthermore, the radar system can handle imperfections of the yaw rate sensor by calibrating the yaw rate sensor and processing measured yaw rate values which are very close to the true yaw rate values.

Brief description of the drawings

An exemplifying embodiment of the invention will now be described below with reference to the accompanying drawings, in which:

Fig. 1 schematically shows a side view of a vehicle on which a radar system according to the present invention has been mounted;

Fig. 2 schematically shows a vehicle carrying a radar system in a system of co-ordinates having the vehicle as a reference; and

Fig. 3 is a flow chart of an embodiment of a method according to the invention.

Detailed description of a preferred embodiment

With reference to Fig. 1, a radar system according to the present invention is schematically shown. The radar system is mounted on a vehicle 110 and includes a radar sensor 100, signal processing means 130 and a yaw rate sensor 140. The radar sensor 100 is located in the front of the vehicle 110 and transmits a radar microwave signal 105 which is reflected by objects (not shown) positioned in front of the vehicle 110. The radar sensor 100 receives the reflected signal and transfers radar measurement data derived from the reflected signal to the signal processing means 130, which is electrically connected to the radar sensor 100. The yaw rate sensor 140 is a horizontal curvature sensor electrically connected to the signal processing means 130. The yaw rate sensor 140 is generally used for course prediction and provides information on the present curvature of the vehicle's directional movement. The yaw rate of the vehicle 110 provided by the yaw rate sensor 140 is fed to the signal processing means 130. To implement an overall system functionality, a number of other means are also mounted on the vehicle 110, such as means for engine and brake control, a man-machine interface, and so on (not shown).

Fig. 2 schematically shows a vehicle 110 carrying a radar system (not shown) in accordance with the present invention. The vehicle 110 is shown in a system of co-ordinates having the vehicle as a reference, i.e. the origin of co-ordinates and the x-axis are equal to the position of the vehicle and the directional axis of the vehicle, respectively. Indicated in the system of co-ordinates is also a stationary object 210, depicted as a dot. Ideally, the radar sensor antenna (not shown) should be aligned with the directional axis of the vehicle, i.e. with the x-axis of the system of co-ordinates.

With reference to Fig. 2 an embodiment of the invention will be described below using the following variables:

$w_{YR}(t)$	which is a measured yaw rate of the vehicle;
$m(t)$	which is a zero drift of the yaw rate sensor;
$k(t)$	which is a scaling factor of the yaw rate sensor;
$\Delta_v(t)$	which is a deviation of an antenna direction from an antenna direction aligned with the directional axis of the vehicle;
$r(t)$	which is a distance to the stationary object from the vehicle;
$\dot{r}(t)$	which is the relative radial speed of the vehicle with respect to the stationary object;
$v(t)$	which is the angle to the stationary object with respect to the x-axis; and
$\dot{v}(t)$	which is the derivative of the angle to the stationary object.

How to derive the variables $r(t)$, $\dot{r}(t)$, $v(t)$ and $\dot{v}(t)$ is well known to a person skilled in the art. The distance

to an object 210 is proportional to the time delay of an emitted radar signal which is reflected by the object 210 and received again. Difference frequencies are obtained by mixing the received signal with the emitted signal and adding frequency shifts resulting from the doppler effect. Using these difference frequencies the distance to the object 210 and the relative radial speed of the object 210 is derived. The determination of the angular position of the object 210 with respect to the sensor axis is done by comparing the amplitudes of the radar reflections of the radar signals with a known antenna pattern.

In order to have a reference for the yaw rate of the vehicle, a reference direction axis is indicated in Fig. 2. Since the system of co-ordinates has the vehicle 110 as a reference, the stationary object 210 can be seen as a moving object in the system of co-ordinates of the vehicle. If the vehicle speed is v_{veh}, the following equations can be derived from Fig. 2:

$$\begin{cases} \dot{r} = -v_{veh} \cdot \cos(\nu) \\ r \cdot \dot{\sigma} = v_{veh} \cdot \sin(\nu) \end{cases} \tag{2.1}$$

Eliminating v_{veh} gives us:

$$\dot{\sigma} = -\frac{\dot{r}}{r} \cdot \tan(\nu) \tag{2.2}$$

In Fig. 2, we also see that:

$$\begin{cases} \dot{\sigma} = \dot{\nu} + \dot{\theta} \\ \dot{\theta} = w \end{cases} \tag{2.3}$$

where w is the true yaw rate of the vehicle with respect to the reference axis. By eliminating $\dot{\theta}$ and $\dot{\sigma}$ in equations 2.2 and 2.3, and by observing the system of Fig. 2 at a point of time t, we arrive at:

$$w(t) = -\dot{v}(t) - \frac{\dot{r}(t)}{r(t)} \cdot \tan\big(v(t)\big) \qquad (2.4)$$

Thus, a theoretical value of the yaw rate of the vehicle can be calculated in accordance with equation 2.4 by the signal processing means 130 using radar measurement data of the signals reflected by the stationary object 220.

With the yaw rate sensor 140, a yaw rate $w_{YR}(t)$ of the vehicle 110 is also measured. However, due to imperfections of the radar system, and its included yaw rate sensor 140, the measured yaw rate value $w_{YR}(t)$ will not be a true yaw rate of the vehicle, but a true yaw rate value affected by at least two presumed radar system parameter errors, the scaling factor $k(t)$ and the zero drift $m(t)$ of the yaw rate sensor. At a given point of time, the zero drift corresponds to an offset included in the measured yaw rate value. Thus, the measured yaw rate value $w_{YR}(t)$, measured with the yaw rate sensor 140, satisfies the following equation:

$$w_{YR}(t) = k(t) \cdot w(t) + m(t) \qquad (2.5)$$

where $w(t)$ is the true yaw rate of the vehicle.

If we assume that our antenna is not properly aligned with the directional axis of the vehicle 110, i.e. with the x-axis, in Fig. 2, but has a deviation $\Delta_v(t)$ from a correct alignment, the system will measure a direction $\tilde{v}(t)$ rather than $v(t)$ to the stationary object 220, where:

$$\tilde{\nu}(t) = \nu(t) - \Delta_{\nu}(t) \tag{2.6}$$

By substituting $\nu(t)$ in equation 2.4, using equation 2.6 and then substituting $w(t)$ in equation 2.5 using equation 2.4, equation 2.5 can be written:

$$w_{YR}(t) = (-\dot{\nu}(t) - \frac{\dot{r}(t)}{r(t)} \cdot \tan(\tilde{\nu}(t) + \Delta_{\nu}(t))) \cdot k(t) + m(t) \tag{2.7}$$

If we assume that the deviation $\Delta_{\nu}(t)$ is small, equation 2.7 can be approximated with:

$$w_{YR}(t) = \left(-\dot{\nu}(t) - \frac{\dot{r}(t)}{r(t)} \cdot \tan\left(\tilde{\nu}(t)\right) \right) \cdot k - \frac{\dot{r}(t)}{r(t)} \cdot \Delta_{\nu}(t) \cdot k + m \tag{2.8}$$

Equation 2.8 can be rewritten as:

$$\frac{w_{YR}(t)}{k} = \left(-\dot{\nu}(t) - \frac{\dot{r}(t)}{r(t)} \cdot \tan(\nu(t)) \right) - \frac{\dot{r}(t)}{r(t)} \cdot \Delta_{\nu}(t) + \frac{m(t)}{k(t)} + e(t)$$

This expression can be divided in to separate expressions for the yaw rate of vehicle 110:

$$\hat{w}_1(t) = -\left(\dot{\nu}(t) + \frac{\dot{r}(t)}{r(t)} \cdot \tan\left(\nu(t)\right) \right) \tag{2.9}$$

and

$$\hat{w}_2(t) = \frac{w_{YR}(t)}{k} + \frac{\dot{r}(t)}{r(t)} \cdot \Delta_{\nu}(t) - \frac{m(t)}{k(t)} \tag{2.10}$$

Thus, we now have two different calculations of the yaw rate, a first calculation given by equation 2.9 and a second calculation given by equation 2.10. The first expression 2.9 provides the yaw rate as a result of calculations based on radar measurement data $v(t)$, $\dot{v}(t)$, $r(t)$ and $\dot{r}(t)$, i.e. the direction to the stationary object 220 in the form of the angle, the derivative of said direction, the distance to the object and a radial relative velocity with respect to the object, respectively, which radar measurement data is received/calculated by the signal processing means 130. The second expression 2.10 provides the yaw rate as a result of calculations based on radar measurement data $w_{YR}(t)$, $r(t)$ and $\dot{r}(t)$. Included in expression 2.10 is furthermore the assumed radar system parameter errors $\Delta_v(t)$, $k(t)$ and $m(t)$ caused by the erroneous alignment of the radar antenna and the scaling factor and zero drift of the yaw rate sensor, respectively.

The difference between the two resulting values of the two expressions 2.9 and 2.10, is a measure of how correct our $k(t)$, $m(t)$ and $\Delta_v(t)$ values are. Thus, by minimising the difference between the two resulting values of the two expressions 2.9 and 2.10 with respect to $k(t)$, $m(t)$ and $\Delta_v(t)$, the result will be derived values of $k(t)$, $m(t)$ and $\Delta_v(t)$ that are best suitable to be used when calibrating the radar system with respect to these system parameters. The calibration with respect to the scaling factor $k(t)$ and zero drift $m(t)$ is preferably a software controlled compensation of the yaw rate values, as measured with the yaw rate sensor 140, and performed by the processing means 130. The calibration with respect to the deviation $\Delta_v(t)$ from a properly aligned antenna is preferably an electrically controlled elimination of this deviation. The elimination is either performed internally of the processing means 130 by compensating radar

measurements for the deviation, or, it is initiated by the processing means 130 and performed by means of an electrically controlled, physical adjustment of the antenna direction.

Our system now takes the following form:

$$\begin{cases} \Theta(t+1) = \begin{pmatrix} \Theta_1(t+1) \\ \Theta_2(t+1) \\ \Theta_3(t+1) \end{pmatrix} = \begin{pmatrix} \Theta_1(t) \\ \Theta_2(t) \\ \Theta_3(t) \end{pmatrix} + \begin{pmatrix} n_1(t) \\ n_2(t) \\ n_3(t) \end{pmatrix} \\ \hat{w}_2(t) = \begin{pmatrix} w_{YR}(t), -1, \dfrac{\dot{r}(t)}{r(t)} \end{pmatrix} \begin{pmatrix} \Theta_1(t) \\ \Theta_2(t) \\ \Theta_3(t) \end{pmatrix} + e(t) \end{cases} \qquad (2.11)$$

where:

$\Theta_1(t) = \dfrac{1}{k(t)}$ is the inversion of the scaling factor of the yaw rate sensor.

$\Theta_2(t) = \dfrac{m(t)}{k(t)}$ is the zero drift of the yaw rate sensor normalised with the scaling factor.

$\Theta_3(t) = \Delta_v(t)$ is the deviation from an optimal antenna alignment.

$n_1(t)$, $n_2(t)$, $n_3(t)$ and $e(t)$ are white noise having a normal distribution with the expected value 0 and variances σ_1^2, σ_2^2, σ_3^2 and σ^2, respectively.

The expression updates now take the following form:

$$\Theta(t+1) = \Theta(t) + K\left(\hat{w}_2(t) - \hat{w}_1(t)\right) \qquad (2.12)$$

We can calculate $m(t)$, $k(t)$ and $\Delta_r(t)$ from the equations of $\Theta_1(t)-\Theta_3(t)$.

To calculate the amplification K it is preferred to either use an RLS (Recursive Least Square) algorithm or a simpler LMS (Least Mean Square) algorithm. Dependant on the chosen algorithm, different number of radar measurements are required to achieve good estimations of the presumed radar system parameter errors. The calculation is also dependant on different time constants, e.g., we can assume that the zero drift error varies within minutes, while the antenna deviation remains unchanged for several years.

With reference to the flow chart of Fig. 3, the embodiment described above will be further illustrated. After start-up of the radar system in step S1, the system is initialised in step S2. The initialisation includes reading the values of Θ_1, Θ_2 and Θ_3 from an internal, non-volatile memory to obtain an initial $\Theta(t)$. These values were previously stored in the memory when the system was last in operation. In step S3, normal radar measurements are performed by transmitting and receiving radar signals. Data is derived from radar signal reflections of a stationary object 210 located in front of the vehicle 110, the data includes an angle to the stationary object 210 with respect to the directional axis of the vehicle 110, a calculated derivative of said angle, a distance to the stationary object 210 and a relative velocity of the vehicle 110 with respect to the stationary object 210. In addition, in step S3, the yaw rate of the vehicle is measured with the yaw rate sensor 140, the measurement being performed at the same time as said data is derived.

In step S4, two estimations of the true yaw rate of the vehicle is provided. The data derived from the signal reflections is used for calculating the first resulting yaw rate as estimation $\hat{w}_1$ in accordance with equation

2.9. The second resulting yaw rate, estimation $\hat{w}_2$, is calculated from the data of the signal reflections and a yaw rate w_{YR} as measured with the yaw rate sensor 140, which measured yaw rate is compensated for presumed radar system parameter errors, all in accordance with equation 2.10. In the described embodiment, these errors are, as described above, the angular deviation Δ_v from an optimal antenna direction and the scaling factor k and zero drift m of the yaw rate sensor 140. In step S5, Θ is updated based on the difference between the first and the second estimation using equation 2.12 and, for example, an LMS algorithm for calculating the amplification K. The resulting $\Theta(t+1)$ is stored in the non-volatile memory and will be used in the next iteration of equation 2.12.

If, in step S6, radar measurements according to step S3 have been performed with respect to a minimum number of stationary objects, for example 300, the process continues to step S7, otherwise the process returns to step S3. In step S7 it is checked whether enough time has elapsed since the system parameter errors were last updated. If this predefined time, for example two minutes, is exceeded the process continues to step S8, otherwise the process returns to step S3. In step S8 the system parameter errors Δ_v, k and m are calculated and updated using the equations of Θ_1, Θ_2 and Θ_3. Finally, the radar system is calibrated using the values calculated in step S8. The process then returns to step S3, and, eventually, a new calibration of the radar system.

Even though the invention has been described with reference to a specific exemplifying embodiment, many different alterations, modifications and the like will become apparent for those skilled in the art. The described embodiment is therefore not intended to limit the scope of the invention, as defined by the appended claims.

CLAIMS

1. A method for performing radar measurements with a vehicle mounted radar system, including the steps of:

assuming that said radar system is associated with parameter errors, which errors include a presumed offset of a horizontal yaw rate sensor measurement and a presumed erroneous alignment of a radar antenna;

transmitting a radar microwave signal;

performing first and second measurements related to a position of a stationary object;

comparing the results from the first and the second measurements, while assigning that at least either of these measurements is dependent upon the assumed parameter errors;

deriving a new presumed yaw rate offset and a new presumed erroneous antenna alignment based on a result of said comparing step; and

performing radar measurements under the assumption of the new derived parameter errors.

2. A method as claimed in claim 1, wherein the included steps are performed during normal operation of the radar system.

3. A method as claimed in claim 1 or 2, wherein said parameter errors further include a scaling factor of said yaw rate sensor measurement.

4. A method as claimed in any one of claims 1 - 3, wherein the steps of performing and comparing the first and second measurements are performed for a predefined number of stationary objects before said deriving step is performed.

5. A method as claimed in any one of claims 1 - 4, wherein said deriving step is performed at regular

intervals during radar measurements with the radar system.

6. A method as claimed in any one of claims 1 - 5, wherein the step of performing radar measurements under the assumption of the new derived parameter errors includes the step of controlling the elimination of the new derived erroneous antenna alignment.

7. A method as claimed in any one of claims 1 - 6, wherein the step of performing radar measurements under the assumption of the new derived parameter errors includes the step of compensating for the new derived yaw rate sensor measurement offset.

8. A method as claimed in any one of claims 3 - 7, wherein the step of performing radar measurements under the assumption of the new derived parameter errors includes the step of compensating for the new derived yaw rate sensor measurement scaling factor.

9. A method as claimed in any one of claims 1 - 8, wherein said erroneous alignment of said antenna is erroneous in a horizontal plane with respect to a directional axis of said vehicle.

10. A method as claimed in any one of claims 1 - 9, wherein said comparing step includes an iterative process in which each iteration involves comparing a first measurement with a second measurement, the iterative process being followed by a calculation of said parameter errors.

11. A method as claimed in any one of claims 1 - 9, wherein said comparing step includes minimising a mean square error between said first and said second

measurements with respect to the presumed parameter errors.

12. A method as claimed in any one of claims 1 - 11, wherein said first and said second measurements are based on radar measurement data which include a direction to said stationary object and a derivative of said direction.

13. A method as claimed in any one of the previous claims, wherein said vehicle is a land based vehicle.

14. A method as claimed in any one of the previous claims, wherein said radar system mounted on said vehicle includes an FMCW-radar.

15. Use of a method as claimed in any one of the previous claims in a vehicle mounted radar system for calibrating the radar system when performing radar measurements with the radar system.

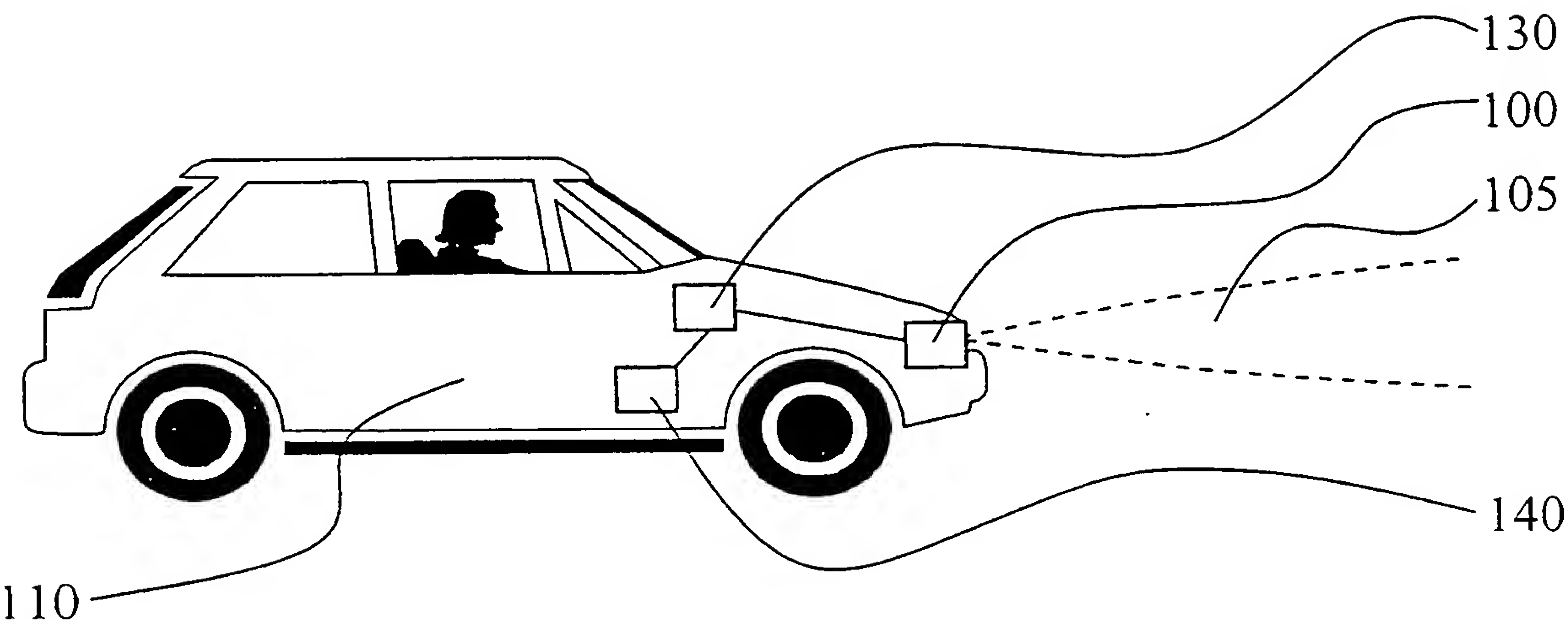

130
100
105
140
110

FIG. 1

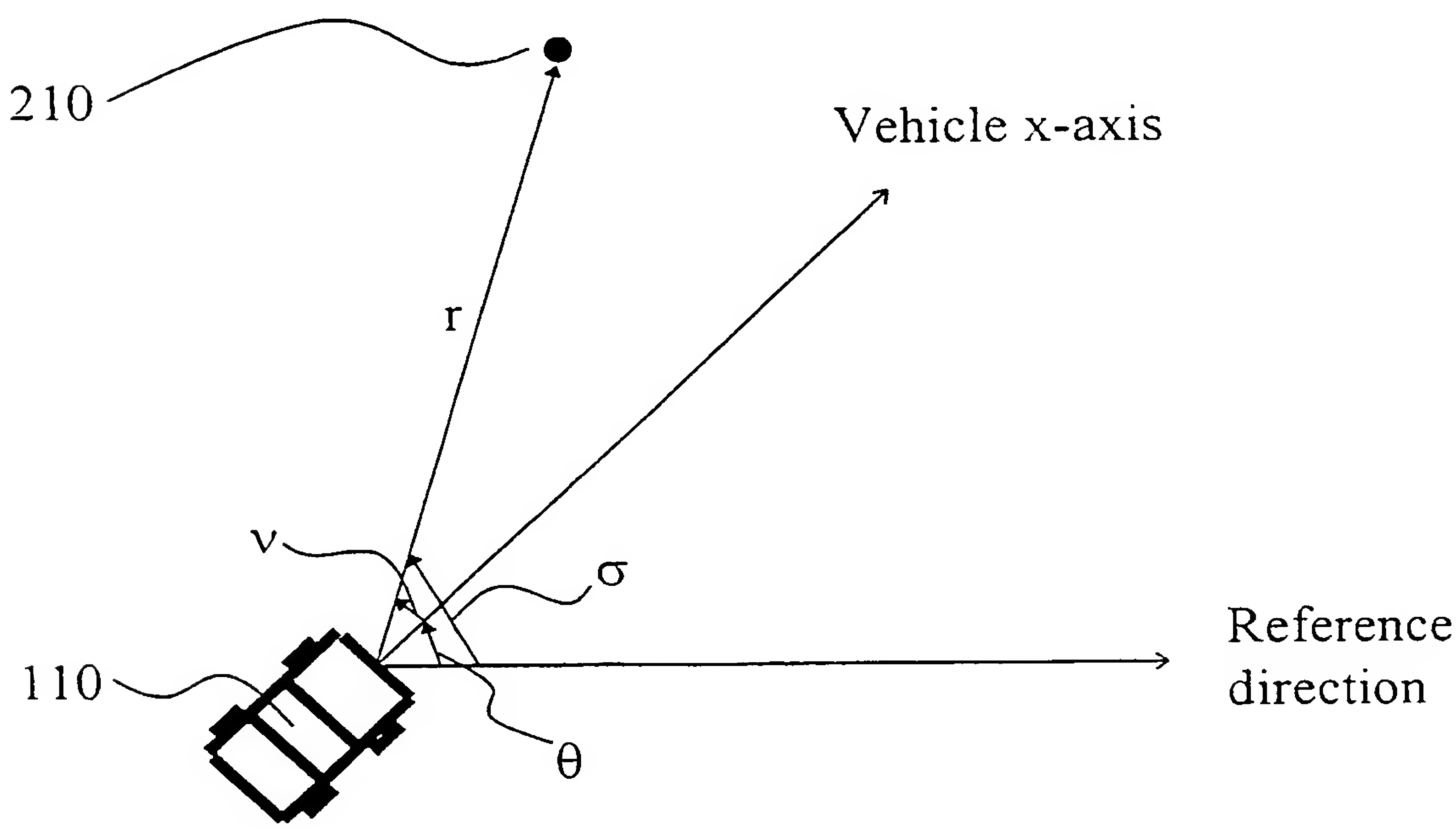
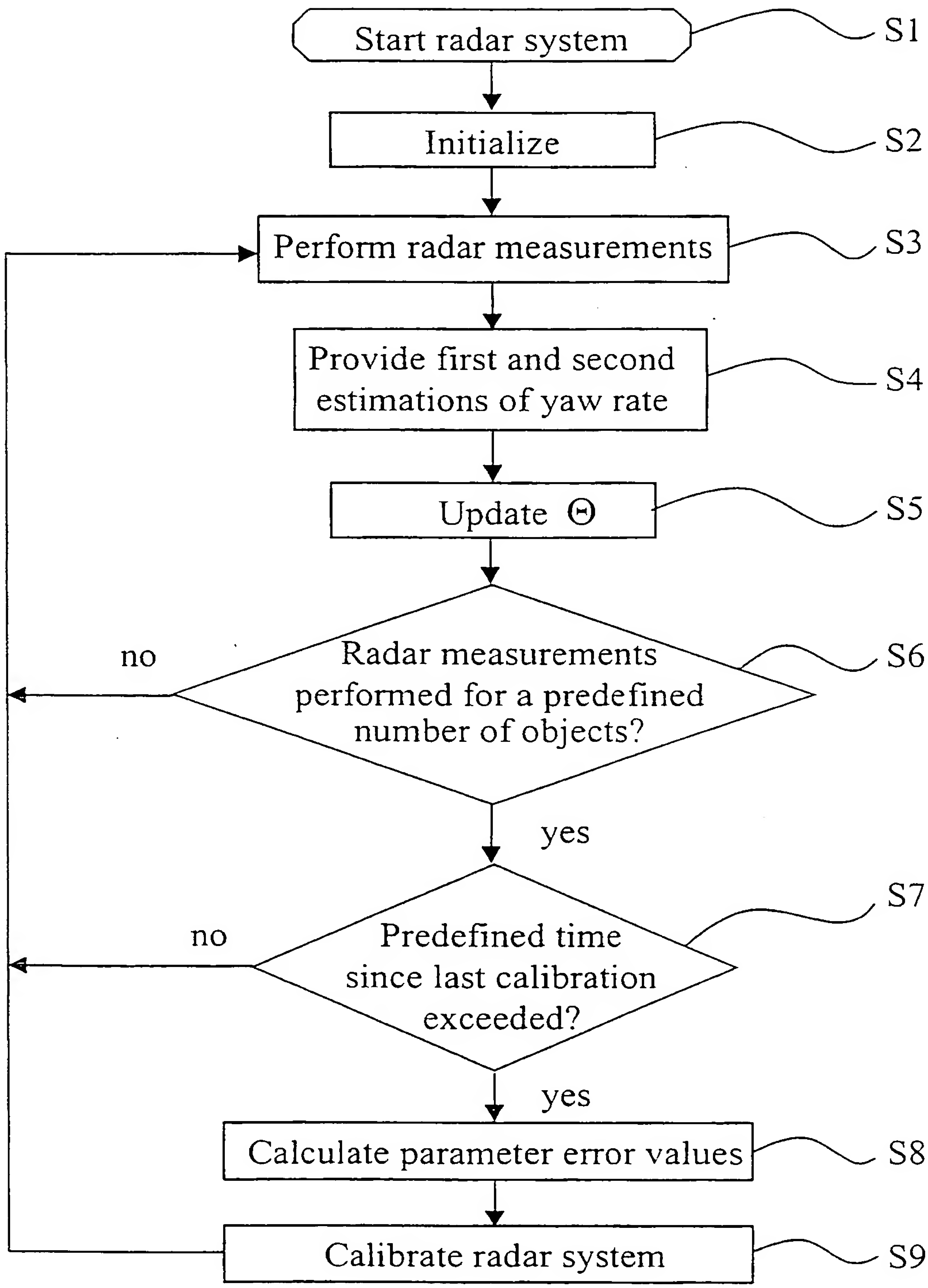

210
Vehicle x-axis
r
ν
σ
110
Reference direction
θ

FIG. 2



Start radar system
S1
Initialize
S2
Perform radar measurements
S3
Provide first and second estimations of yaw rate
S4
Update Θ
S5
Radar measurements performed for a predefined number of objects?
S6
no
yes
Predefined time since last calibration exceeded?
S7
no
yes
Calculate parameter error values
S8
Calibrate radar system
S9

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01191

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01S 7/40, G01S 13/93
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0899581 A2 (DELCO ELECTRONICS CORPORATION), 3 March 1999 (03.03.99), page 1, line 34 - line 45; page 2, line 27 - line 54 --	1-15
A	US 5670963 A (Y. KUBOTA ET AL), 23 Sept 1997 (23.09.97), column 1, line 53 - column 2, line 42; column 3, line 21 - line 54 --	1-15
A	WO 9926082 A1 (DAIMLER-BENZ AKTIENGESELLSCHAFT), 27 May 1999 (27.05.99), abstract --	1-15
A	US 5495254 A (H. UEMURA ET AL), 27 February 1996 (27.02.96), abstract --	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 Sept 2000	21 -09- 2000

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Göran Magnusson/AE Telephone No. + 46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/08/00

International application No.
PCT/SE 00/01191

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0899581 A2	03/03/99	US 5964822 A	12/10/99
US 5670963 A	23/09/97	DE 19610351 A	26/09/96
		JP 8320371 A	03/12/96
WO 9926082 A1	27/05/99	DE 19751004 A	20/05/99
US 5495254 A	27/02/96	DE 4339371 A	26/05/94
		JP 6160510 A	07/06/94